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Model
390A3

OPERATING INSTRUCTIONS

for

MICROWAVE CRYSTAL TEST SET

#4949

Airborne Instruments Laboratory
INCORPORATED
160 OLD COUNTRY ROAD · MINEOLA, N.Y.

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MICROWAVE CRYSTAL TEST SET

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Figure 1. AIL Type 390A-3 Test Set

PART I

PURPOSE

The microwave crystal test set (Figure 1)* gives an indication of the important performance characteristics of microwave crystals. To a large extent, these characteristics determine the performance of such crystals in mixer and detector applications. A simple d-c technique is used to measure quantities that are mathematically related to crystal performance. The Test Set may be used for the following purposes:

1. To measure the relative noise figure of microwave mixer crystals;
2. To obtain an approximate impedance check for selecting matched crystals for use in balanced mixers;
3. To measure the relative sensitivity of microwave detector crystals.

*These instructions apply to two models of the Test Set: Type 390-1 and Type 390A-3. They are similar; where the text deals with features in which they differ, the difference is described in footnotes.

Since the Test Set uses a d-c test only, it does not measure the effects of shunt capacitance or absolute r-f impedance in any particular microwave equipment. For crystals that have passed JAN acceptance tests, however, the Test Set results are accurate because the capacitance and r-f impedance variations of JAN crystals are small.

PART II

THEORY OF OPERATION

BASIC PRINCIPLES

For unbalanced-mixer operation, the quality of a mixer crystal can be determined by measuring its noise figure, which is the product of its conversion loss and noise temperature. Conversion loss is defined as the ratio of the power available from the r-f signal source to the power available at the i-f output of the mixer; noise temperature is defined as the ratio of the i-f noise power available from the crystal to the thermal noise power available from a resistor at room temperature. Balanced mixers require crystals whose i-f impedances, as well as conversion losses, are closely matched, if full advantage of such a mixer is to be obtained. The design of the Test Set is based on the fact that the low-frequency conversion loss can be determined from the degree of nonlinearity of the static voltage-current (E-I) curve of a mixer crystal. The UHF or SHF conversion loss depends upon how the crystal is matched at the signal frequency and terminated at the sum and image frequencies.* The Test Set measures the nonlinearity of the E-I curve by measuring the incremental change in crystal current caused by an incremental change in voltage applied in the "forward" direction. The Test Set is calibrated so that, if the E-I curve of the crystal being tested is linear, the corresponding TEST meter reading will be approximately at mid-scale; if the E-I curve is nonlinear, the TEST meter reading will be below mid-scale. The amount by which the reading falls

*For a detailed discussion of the performance of mixer crystals, see *Some Aspects of Mixer Crystal Performance,* by P. D. Strum, PROC. I.R.E., vol. 41, p 875-889, July 1953. For a further discussion, see *Mixer Crystal Checker,* by P. D. Strum, ELECTRONICS, p 94-97, December 1950.

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below mid-scale is a measure of the degree of nonlinearity: the lower the meter reading, the more nonlinear is the E-I curve of the crystal, and consequently the lower is its conversion loss.

Figure 2 is a schematic diagram of the Test Set.* The initial value of voltage V_1 is established by adjusting variable resistor R101 with CAL-TEST switch S101 in the CAL position. With the crystal in holder X101, R101 is adjusted until its control-knob pointer and the meter pointer indicate the same value. S101 is then switched to the TEST position, which establishes an additional increment of voltage $\triangle e$ across the crystal under test. The resistance of R101, R102, R104, R105, and R106 determines the initial (CAL) voltage; the resistance of R103 and R107 determines the voltage incre-

*In the AIL Type 390-1 Test Set, S102 and R108 are not included. Instead, X101 and J101 are connected directly into the circuit, with the polarity such that the point marked A is connected to the positive terminal of M101 and to ground. In addition, the center contact of Section 2 of S101 is connected to ground instead of to the positive terminal of M101.

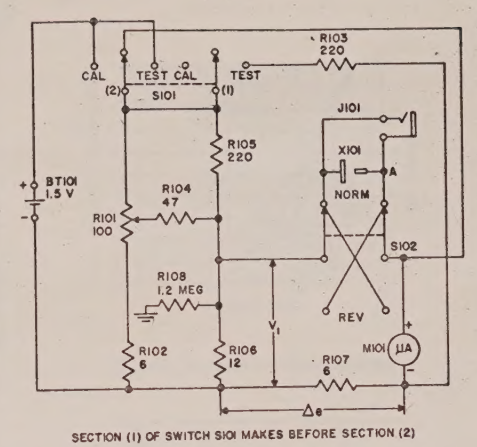

Figure 2. Schematic Diagram of AIL Type 390A-3 Test Set

ment applied to the crystal when S101 is set to the TEST position. This increment is the same for all crystals. The current indicated on M101 with S101 in the TEST position is a measure of the nonlinearity of the E-I curve of the crystal, and hence of its conversion loss and approximate noise temperature.

CALIBRATION CURVES

For the AIL Type 390A-3 Test Set, three noise-figure curves are shown in Figure 3 and on the chart inside the cover of the case assembly—two for crystals alone and one for a crystal in a typical microwave superheterodyne receiver.* The curve for 0.8 ma corresponds approximately to JAN test conditions for S-band crystals, and the curve for 1.2 ma to test conditions for X-band crystals. Figure 4 shows a typical noise-figure error distribution, as determined by comparing actual noise-figure measurements with Test Set readings. The "typical superheterodyne" curve of Figure 3 depends upon the actual receiver design. R-F losses will move the curve vertically — upward with increased losses, and downward with decreased losses. I-F noise figure and local-oscillator noise change the slope of the curve—low i-f noise

*Crystal noise figure (F_x) is equal to the product of conversion loss (L_c) and noise temperature (t) when both are in power ratio units. Receiver noise figure (F_R) can be computed from the relation

$$F_R = L_r L_c (F_i + t - 1)$$

where L_r is the r-f loss and F_i is the i-f noise figure.

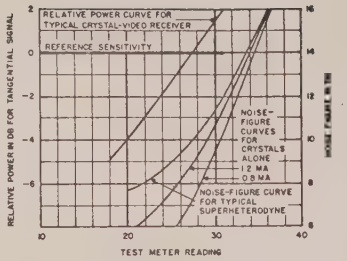
RELATIVE POWER CURVE FOR TYPICAL CRYSTAL-VIDEO RECEIVER
REFERENCE SENSITIVITY
NOISE-FIGURE CURVES FOR CRYSTALS ALONE
1.2 MA
0.8 MA
NOISE-FIGURE CURVE FOR TYPICAL SUPERHETERODYNE
RELATIVE POWER IN DB FOR TANGENTIAL SIGNAL
NOISE FIGURE IN DB
TEST METER READING

Figure 3. Calibration Curves

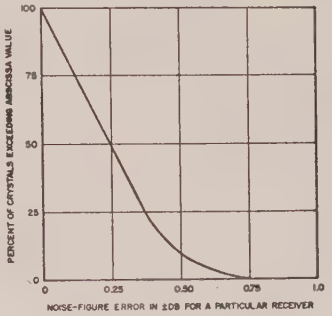

Figure 4. Distribution of Noise-Figure Errors

figure and local-oscillator noise increasing the slope, and vice versa. For many receivers, the "typical superheterodyne" curve in Figure 3 gives a good estimate of relative receiver noise figure.

Figure 5 shows Test Set calibration in terms of conversion loss and noise temperature as measured under the same conditions as those in Figure 3.*

*The curves for 0.8 ma are the same as those supplied inside the case-assembly cover of the AIL Type 390-1 Test Set.

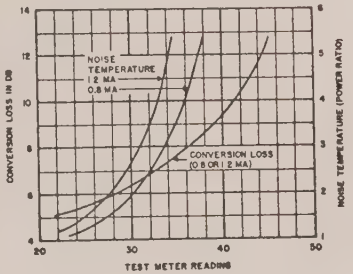

Figure 5. Conversion-Loss and Noise-Temperature Curves

MATCHING MIXER-CRYSTAL PAIRS

In receivers using balanced mixers, the crystal pairs should be matched for conversion loss and i-f impedance.* The Test Set gives indications of both these parameters: the TEST meter reading indicates available conversion loss, and the CAL meter reading indicates relative i-f impedance. To match a pair of crystals, it is only necessary to pair two crystals whose CAL and TEST readings are approximately equal. (The crystals must be of the same designated type, except that one member of the pair may be of reversed polarity carrying the suffix R.†)

MICROWAVE DETECTOR CRYSTALS

In some receivers such as crystal-video types, microwave detector crystals are used to detect microwave signals by square-law

*For a discussion of the matching requirements, see *Microwave Mixers*, by R. V. Pound, Radiation Laboratory Series, vol. 16, p 273, McGraw-Hill, 1948.

†The AIL Type 390-1 Test Set does not have provision for testing reversed-polarity crystals, except by the use of an external adapter.

action. Since the detecting action is different from the mixing action of mixer crystals, a different set of test conditions is required for these crystals. The sensitivity of this type of crystal is dependent upon two characteristics—the degree of nonlinearity and the video resistance.

The procedure for testing detector crystals (types 1N31 and 1N32)* is similar to that for testing mixer crystals, except that all units of a single type are set to one particular initial current, rather than to various initial currents as is the case for mixer crystals.

The "typical crystal-video receiver" curve in Figure 3 indicates the sensitivity of microwave detector crystals. For a crystal-video receiver, sensitivity is measured in terms of the available r-f signal power required to give an 8-db output signal-to-noise ratio; a signal of this power level is termed a tangential signal. The reference sensitivity is the accept-reject limit and is determined by the bandwidth of the video amplifier and by r-f losses. Typical values of reference sensitivity lie between –40 dbm and –50 dbm. Errors in indicating the sensitivity of microwave detector crystals are about twice those shown in Figure 4 for mixer crystals.

*The AIL Type 390-1 Test Set has no provision for testing these types of detector crystals.

PART III
OPERATING INSTRUCTIONS

TESTING CRYSTALS FOR USE IN UNBALANCED MIXERS

CAUTION: To prevent excessive meter currents, which might result when a damaged or low-resistance crystal is being tested, turn the control knob for variable resistor R101 to a setting between 70 and 80.

*Making Preliminary Adjustments.** Set the NORM-REV switch (S102) to the appropriate position for the crystal to be tested. Use the NORM position for all crystals whose types are listed on the face of the meter; use

*This procedure applies only to the AIL Type 390A-3 Test Set. To test reversed-polarity crystals in the AIL Type 390-1 Test Set, it is necessary to use an adapter to reverse the polarity at crystal holder X101.

the REV position for all types with the suffix R (for example, type 1N23BR). Since normal or reversed-polarity crystals may be encountered and since either end of the crystal may be grounded in a remotely located holder, use the NORM-REV switch to choose the proper polarity by trial. Choose the position giving the higher current reading.

Inserting the Crystal. Before inserting a crystal into the crystal holder (X101), hold the crystal by the base, and touch the hand containing the crystal to the metal case of the Test Set to remove electrostatic charges. The REMOTE TEST JACK can be used to connect the Test Set to a remotely located crystal. The connections to the crystal should be made through a cable and any intervening circuitry that introduces a low d-c resistance (less than 10 ohms). The REMOTE TEST JACK provides a set of terminals in parallel with the crystal holder.

Calibrating the Test Set. Set the CAL-TEST switch (S101) to the CAL position, and hold it in that position. Adjust the variable resistor (R101) until the control-knob pointer and the meter pointer indicate the same value.

Testing the Crystal. Without changing the setting of the control-knob pointer, set the CAL-TEST switch to the TEST position, and read the indication of crystal quality on the meter: the lower the reading, the better the crystal. Refer to Figure 3 to determine the crystal noise figure or to estimate the relative receiver noise figure. (See paragraph headed "Calibration Curves" in Part II.)

Removing the Crystal. Before reinstalling the mixer crystal in the microwave receiver, hold the crystal by the base and touch the base to the mixer assembly. This procedure will reduce the possibility of crystal burnout due to electrostatic charges.

TESTING CRYSTALS FOR USE IN BALANCED MIXERS

Follow the same procedure as for testing crystals for use in unbalanced mixers. Pair crystals having CAL readings that are approximately equal and TEST readings that are also approximately equal. It is desirable that each reading be matched within ½ scale unit. If it is not possible to find pairs matched within these limits, it is preferable that differences be in the same direction for

the two readings; for instance, a crystal with a reading of 63/24 should be paired with a crystal with a reading of 65/25 rather than with a crystal with a reading of 65/23. In any group of a dozen or more usable crystals, it is usually possible to group all or nearly all into matched pairs.*

If a pair of crystals is well matched on CAL and TEST readings, the mixer performance is given by the same calibration curves and accuracies as those indicated for unbalanced-mixer performance.

TESTING MICROWAVE DETECTOR CRYSTALS†

After making the preliminary adjustments and inserting the crystal, set the CAL-TEST switch (S101) to the CAL position, and adjust R101 until the pointer on the meter reads at the point on the scale marked in red and designated for that particular type of crystal. Set switch S101 to the TEST position, and note the indication on the meter. Crystal quality can then be determined from Figure 3 or from the calibration chart inside the cover of the case assembly.

*It should be noted, however, that the Test Set cannot choose pairs with r-f impedances matched to the accuracy presently required for crystals having the suffix M. Since r-f impedance balance is of importance only in reducing local-oscillator radiation from the antenna and not in determining local-oscillator noise suppression, this does not affect the accuracy of the Test Set in measuring noise figure.

†This test procedure applies only to the AIL Type 390A-3 Test Set.